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Penetration of 15-Grain Bomb Fragments Into Wallboard

TECHNICAL REPORT AFATL-TR-70-18

FEBRUARY 1970

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EGLIN AIR FORCE BASE, FLORIDA

26

PENETRATION OF 15-GRAIN BOMB FRAGMENTS INTO WALLBOARD

by

Richard P. Warnis

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FOREWORD

Presently, the Degradation Effects Program (DEP) and others are using regression equations relating the striking velocity for cylinders as a function of their penetration into wallboard. This effort grew out of the question of whether actual bomb fragments would have a similar regression equation. This phase of the study is concerned with testing 15-grain bomb fragments. As a follow-up study, 60-grain and 240-grain bomb fragments will be investigated.

The author wishes to thank R. Brandt (ATRD) for his suggestions on analytical techniques for data evaluation. The ATRD range crew composed of Jack Byrne, Clyde Wallace, Sgt Ron Stearns, Sgt John Frayer, Sgt T.C. Costello, and A1C Earl Farabaugh provided the necessary technical support and instrumentation.

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This technical report has been reviewed and is approved.

CHARLES K. ARPKE, Lt Col, USAF
Acting Chief, Technology Division

ABSTRACT

The primary objective of this program was to define a function between the striking velocity for 15-grain random shaped bomb fragments and their depth into the wallboard trade named Nu-Wood. These fragments were fired from a 20mm Mann barrel into bundled Nu-Wood. The fragments were lightly filed to fit into a $0.97 \leq w \leq 1.03$ gram weight range. The striking velocities were in the 500 ft/sec to 5000 ft/sec range. The graph of fragment striking velocity as a function of depth into Nu-Wood showed a wide range of depths for approximately 1000 ft/sec, 3000 ft/sec, and 5000 ft/sec striking velocities. A least squares curve would not be valuable since the penetration spread is too wide at given velocities. Fragment penetration into Nu-Wood from firing cylinders does not give a realistic picture of 15-grain actual bomb fragmentation spread. The fragment penetration into Nu-Wood was found to be a momentum as opposed to a kinetic energy effect. The depth of penetration is not a primary function of the presented area and perimeter of the impacting fragments for 3000 ft/sec and 5000 ft/sec velocities. Shots at 1000 ft/sec reveal a dependence on the presented area and perimeter of the impacting fragment.

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SECTION I
INTRODUCTION

Actual 15-grain bomb fragment firings into Nu-Wood were conducted at Range 22, Eglin AFB, during the months of July through September 1969.

The primary objective was to define a function between striking velocity and depth into Nu-Wood. Secondary objectives were:

a. To find if the penetration into Nu-Wood is a function of the presented area and perimeter of the impacting fragment.

b. To determine if the penetration of actual 15-grain bomb fragments into Nu-Wood is a momentum or kinetic energy effect.

c. To observe the breakup characteristics of actual 15-grain bomb fragments in Nu-Wood.

d. To determine the extent of deflection of the fragments relative to projected paths in air and Nu-Wood.

SECTION II
TEST SET-UP

The general test set-up for the firings is shown in Figure 1. Figure 2 shows the co-ordinates X_1Y_1, X_2Y_2, and X_3Y_3 on the three-dimensional view of the bundle. The lower left hand corner of the bundle serves as the origin.

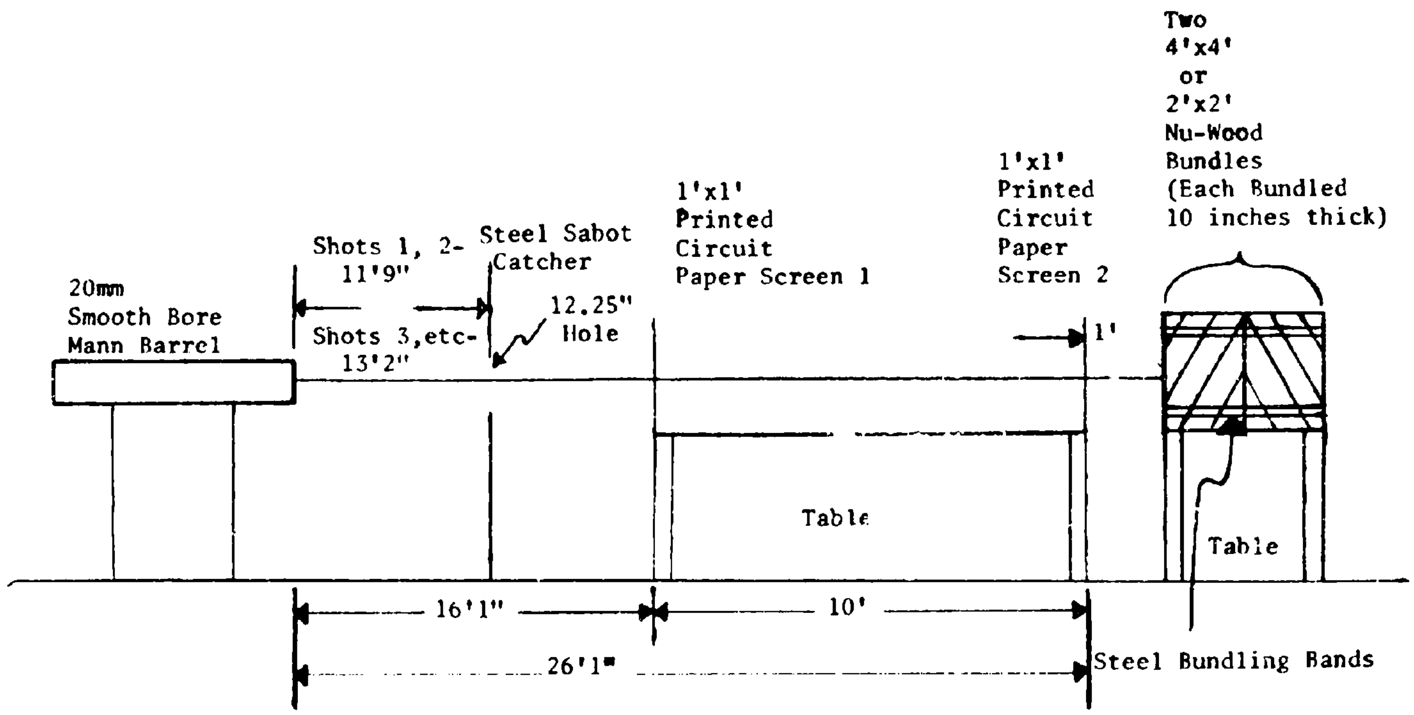


Figure 1. Test Set-up

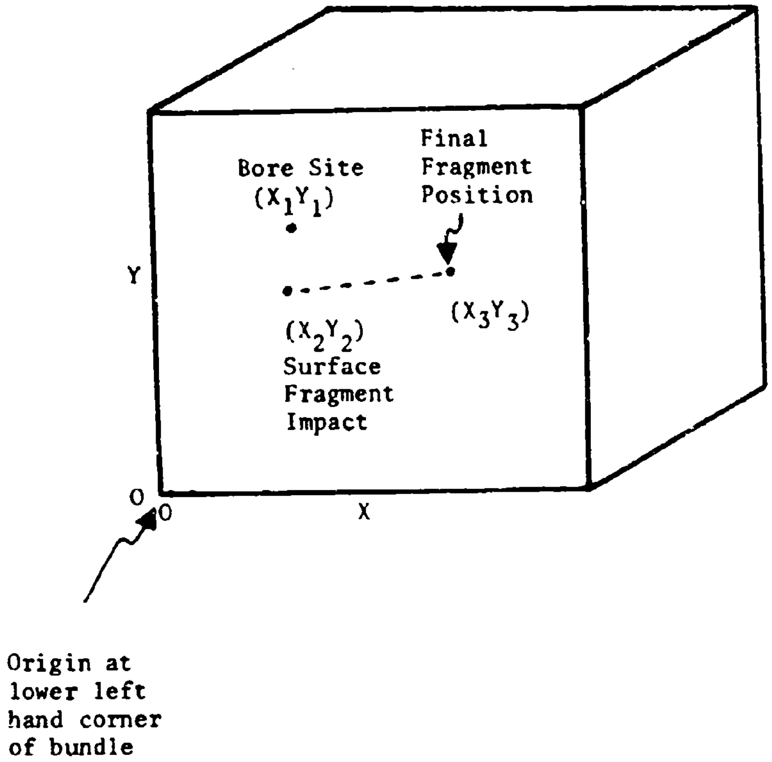


Figure 2. X and Y Co-ordinates on the Nu-Wood Bundle.

SECTION III
PRIMARY OBJECTIVE

Figure 3 shows the finalized graph of striking velocity as a function of depth of penetration into Nu-Wood. These striking velocities were obtained by correcting the fragment measured velocity for air drag. The air drag correction was 0.9242 times the measured velocity to give the striking velocity. This was obtained from: [1]

$$V_s = \bar{V} \left[\frac{e^{\frac{-\alpha(S-x)}{m^{1/3}}} - e^{\frac{-\alpha S}{m^{1/3}}}}{\frac{\alpha x}{m^{1/3}}} \right]$$

V_s = Striking velocity (feet/sec).

$\bar{V}$ = Average measured velocity between the screens. The first screen is at $x_0=0$, the second at $x=10$ feet (ft/sec),

S = Distance from the first screen to the target (11 feet).

α = 0.0327 (constant for an air drag coefficient $C_d = 0.640$, and density of air, $\rho = 0.310$ grains/in^3).

M = Mass of fragment in grains.

Valid data points and data points estimated from powder charges are plotted on Figure 3. The fragment weight range of $0.97 \leq w \leq 1.03$ grams is not a function of depth into Nu-Wood. Figure 3 illustrates the wide spread in depth of penetration at striking velocities near 3000 ft/sec and 5000 ft/sec.

A means of classification of the fragments into shape categories was found from close examination of the fragments and solving for D in:

$$LWD = \frac{w}{\rho}$$

LWD = Length Width Depth where L>W>D (in.).

w = Weight of fragment (lbs).

ρ = 0.284 $\frac{\text{lbs}}{\text{in}^3}$ as the general density of steel.

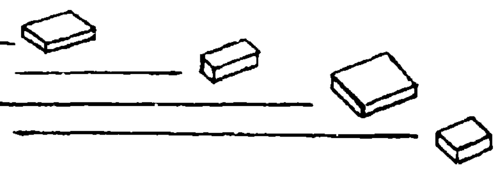
The Categories are:

L-F = Long flat, fragment 3

L-C = Long chunky, fragment 20

F = Flat, fragment 4

F-C = Flat chunky, fragment 2



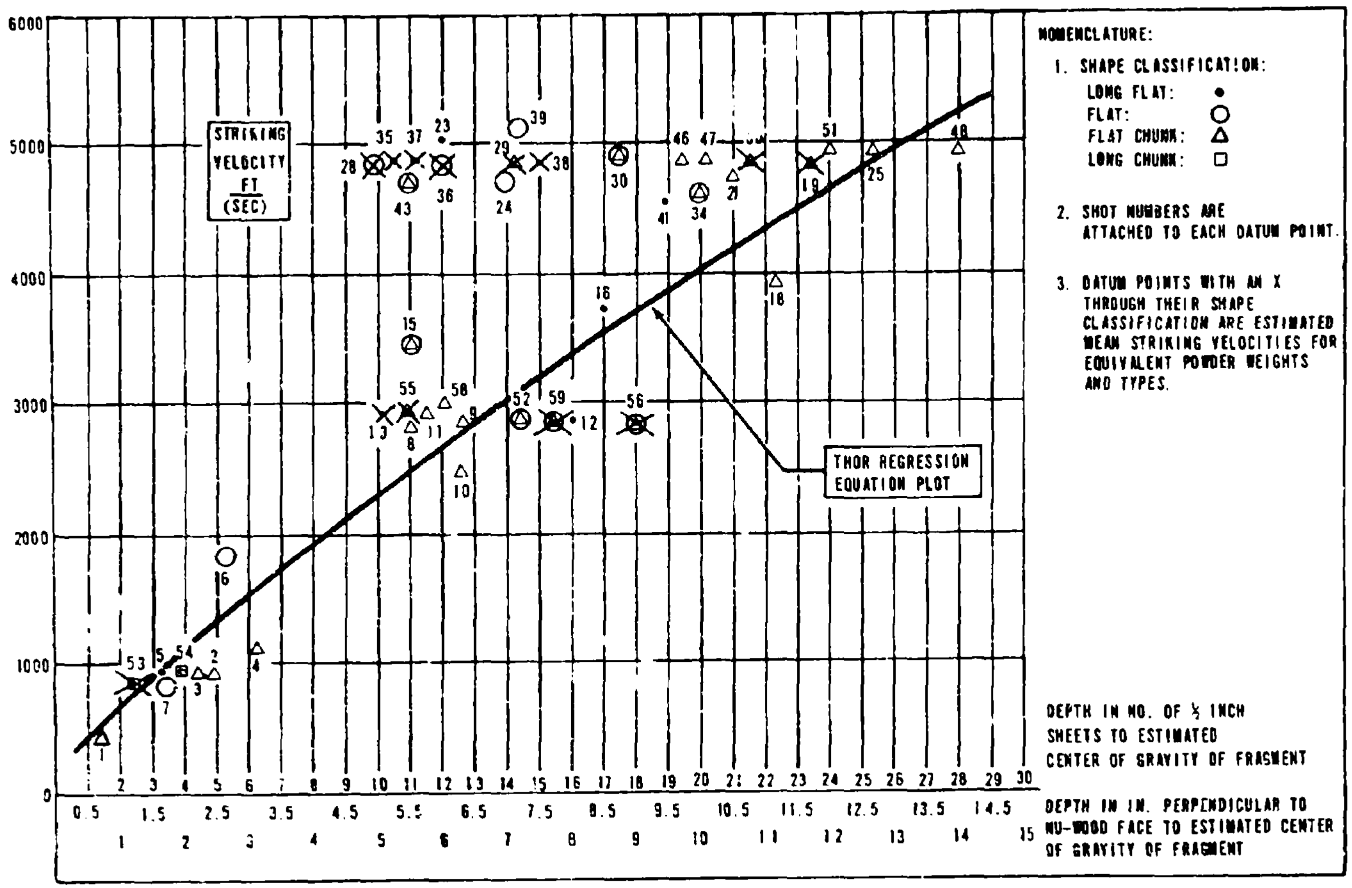


Figure 3. Striking Velocity versus Penetration into Nu-Wood for 15-Grain Bomb Fragments.

The calculated D values can fit approximate groups for D (inches):

Long Flat	Flat	Flat Chunky	Long Chunky
0.045	045<0.055	0.055<0.065	0.065<0.075

Table 1 shows the classification of the fragments and Figure 4 illustrates the fragments. Figure 4 fragments 1 through 20 were not photographed before the firings. After firing, many fragments were lost from impacting the sabot catcher or the printed circuit paper holders.

The data points in Figure 5 have associated fragment shape classifications. Generally, the long flats and flats are distributed to the extreme left of the graph. Long chunks and flat chunks are primarily concentrated toward the middle and extreme right of the graph.

Figure 3 has a regression plot of a penetration equation obtained by firing steel cylinders into wallboard trade named Nu-Wood and Flint-Kote. These cylinders had characteristic velocities from 305 ft/sec to 12,788 ft/sec, masses from 0.25 grains to 241.50 grains, and 0° to 70° obliquity from the projectile path to the perpendicular to the Nu-Wood surface. The finalized regression equation used for the plot is: [7]

$$V_s = \frac{112881(X)^{0.8093}(KM^{2/3})^{0.9078}}{M^{0.9380}}$$

V_s = Striking velocity of steel cylindrical fragments (ft/sec)

X = Depth of penetration measured perpendicular to the Nu-Wood surface (in.)

K = 0.0088

M = Mass of fragment (grains)

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[7] This will be termed the Thor regression equation. The Thor regression plot for cylinders does not fit closely to the distribution of 15-grain bomb fragment data points. Long chunks and flat chunks do fit within an acceptable range of the Thor Plot.

TABLE I. 15 GRAIN BOMB FRAGMENT SHAPE CLASSIFICATION, POWDER CHARGE, MEASURED VELOCITY, STRIKING VELOCITY, AND PENETRATION INTO NU-WOOD DATA.

Shot No.	Fragment No.	Shape Classification	Powder Weight (Grains), Type	Measured Velocity (ft/sec)	Striking Velocity (0.9242 X Measured Velocity) (ft/sec)	Nu-Wood Fragment Penetration Depth Perpendicular to Nu-Wood Surface to Estimated Center of Gravity of Fragment (in.)	Comments
1	Fragment 15	Flat Chunk	125 Grains IMR 4350	463	428	0.75	Good Shot
2	Fragment 15	Flat Chunk	175 Grains IMR 4350	981	907	2.25	Good Shot
3	Fragment 1	Flat Chunk	175 Grains IMR 4350	982	908	2.19	Good Shot
4	Fragment 2	Flat Chunk	180 Grains IMR 4350	1212	1120	3.12	Good Shot
5	Fragment 3	Long Flat	175 Grains IMR 4350	1010	933	1.69	Good Shot
6	Fragment 16	Flat	300 Grains IMR 4350	1974	1824	2.69	Good Shot
7	Fragment 4	Flat	175 Grains IMR 4350	906	837	1.75	Good Shot
8	Fragment 5	Flat Chunk	400 Grains IMR 4350	3034	2804	5.50	Good Shot
9	Fragment 6	Flat Chunk	400 Grains IMR 4350	3083	2849	6.31	Good Shot
10	Fragment 7	Flat Chunk	335 Grains IMR 4350	2656	2455	6.25	Good Shot
11	Fragment 8	Flat Chunk	400 Grains IMR 4350	3112	2876	5.56	Good Shot
12	Fragment 9	Long Flat	390 Grains IMR 4350	3111	2875	8.00	Good Shot
13	Fragment 10	Long Flat	390 Grains IMR 4350	2232 (3111)	2063 (2875)	5.50	Bad Shot
14	Fragment 10	Long Flat	390 Grains IMR 4350	1790	1654	N/A	Bad Shot
15	Fragment 11	Flat, Flat Chunk	550 Grains IMR 4350	3748	3464	5.50	Good Shot
16	Fragment 12	Long Flat	550 Grains IMR 4350	4010	3706	8.50	Good Shot
17	Fragment 13	Flat, Flat Chunk	325 Grains IMR 4895	N/A	N/A	5.00	Bad Shot
18	Fragment 18	Flat Chunk	500 Grains IMR 4895	4267	3944	11.12	Good Shot
19	Fragment 15	Flat Chunk	600 Grains IMR 4895	N/A (5252)	N/A (4854)	11.75	Bad Shot
20	Fragment 15	Flat Chunk	625 Grains IMR 4895	N/A	N/A	N/A	Bad Shot
21	Fragment 1	Flat Chunk	625 Grains IMR 4895	5180	4787	10.50	Good Shot
22	Fragment 19	Flat, Long Flat	625 Grains IMR 4895	4017	3713	5.00	Bad Shot Breakoff
23	Fragment 17	Long Flat	625 Grains IMR 4895	5423	5012	6.00	Good Shot
24	Fragment 4	Flat	625 Grains IMR 4895	5171	4779	7.00	Good Shot
25	Fragment 2	Flat Chunk	625 Grains IMR 4895	5327	4923	12.62	Good Shot
26	Fragment 14	Long Flat	625 Grains IMR 4895	3879	3585	N/A	Bad Shot
27	Fragment 16	Flat	625 Grains IMR 4895	4378	4046	N/A	Bad Shot
28	Fragment 16	Flat	625 Grains IMR 4895	4438 (5252)	4102 (4854)	5.00	Bad Shot
29	Fragment 8	Flat Chunk	625 Grains IMR 4895	N/A (5252)	N/A (4854)	7.25	Bad Shot
30	Fragment 11	Flat, Flat Chunk	625 Grains IMR 4895	5288	4887	8.75	Good Shot

TABLE I. (CONT'D)

Shot No.	Fragment No.	Shape Classification	Powder Weight (Grains), Type	Measured Velocity (ft/sec)	Striking Velocity (0.9242 X Measured Velocity) (ft/sec)	Nu-Wood Fragment Penetration Depth Perpendicular to Nu-Wood Surface to Estimated Center of Gravity of Fragment (in.)	Comments
31	Fragment 3	Long Flat	625 Grains IMR 4895	4730	4371	N/A	Bad Shot Breakoff
32	Fragment 8	Flat Chunk	625 Grains IMR 4895	3894	3599	N/A	Bad Shot Fragment Hit Sabot Catcher
33	Fragment 4	Flat	625 Grains IMR 4895	3768	3482	N/A	Bad Shot Fragment Hit Sabot Catcher
34	Fragment 11	Flat, Flat Chunk	625 Grains IMR 4895	5005	4626	10.00	Good Shot
35	Fragment 17	Long Flat	625 Grains IMR 4895	3779(5252)	3493(4854)	5.25	Bad Shot
36	Fragment 16	Flat	625 Grains IMR 4895	1678(5252)	1551(4854)	6.00	Bad Shot
37	Fragment 10	Long Flat	625 Grains IMR 4895	1620(5252)	1497(4854)	5.62	Bad Shot
38	Fragment 10	Long Flat	625 Grains IMR 4895	3295(5252)	3045(4854)	7.50	Bad Shot
39	Fragment 16	Flat	625 Grains IMR 4895	5537	5117	7.12	Good Shot
40	Fragment 12	Long Flat	625 Grains IMR 4895	534 (Muzzle Blast)	494	N/A	Bad Shot
41	Fragment 9	Long Flat	625 Grains IMR 4895	4933	4559	9.50	Good Shot
42	Fragment 11	Flat, Flat Chunk	625 Grains IMR 4895	454 (Muzzle Blast)	420	N/A	Bad Shot
43	Fragment 13	Flat, Flat Chunk	625 Grains IMR 4895	5155	4764	5.50	Good Shot
44	Fragment 16	Flat	625 Grains IMR 4895	1788	1652	N/A	Bad Shot
45	Fragment 1	Flat Chunk	625 Grains IMR 4895	3510	3244	N/A	Bad Shot
46	Fragment 2	Flat Chunk	625 Grains IMR 4895	5269	4870	9.75	Good Shot
47	Fragment 18	Flat Chunk	625 Grains IMR 4895	1910(5252)	1765(4854)	10.00	Bad Shot
48	Fragment 2	Flat Chunk	625 Grains IMR 4895	5368	4961	14.00	Good Shot
49	Fragment 18	Flat Chunk	625 Grains IMR 4895	1573	1454	N/A	Bad Shot
50	Fragment 2	Flat Chunk	625 Grains IMR 4895	3293(5252)	3043(4854)	10.75	Bad Shot
51	Fragment 2	Flat Chunk	625 Grains IMR 4895	5370	4963	12.00	Good Shot
52	Fragment 13	Flat, Flat Chunk	400 Grains IMR 4350	3154	2915	7.38	Good Shot
53	Fragment 20	Long Flat, Long Chunk	175 Grains IMR 4350	636(972)	588(898)	1.25	Bad Shot
54	Fragment 20	Long Flat, Long Chunk	175 Grains IMR 4350	982	908	2.00	Good Shot
55	Fragment 5	Flat Chunk	400 Grains IMR 4350	2231(3111)	2062(2875)	5.50	Bad Shot
56	Fragment 13	Flat, Flat Chunk	400 Grains IMR 4350	2609(3111)	2411(2875)	9.00	Bad Shot
57	Fragment 9	Long Flat	400 Grains IMR 4350	1482	1370	N/A	Bad Shot

TABLE I. (CONT'D)

Shot No.	Fragment No.	Shape Classification	Powder Weight (Grains), Type	Measured Velocity (ft/sec)	Striking Velocity (0.9242 X Measured Velocity) (ft/sec)	Nu-Wood Fragment Penetration Depth Perpendicular to Nu-Wood Surface to Estimated Center of Gravity of Fragment (in.)	Comments
58	Fragment 6	Flat Chunk	400 Grains IMR 4350	3256	3009	6.00	Good Shot
59	Fragment 3	Flat, Flat Chunk	400 Grains IMR 4350	410(3111) (Muzzle Blast)	379(2875)	7.75	Bad Shot
60	Fragment 20	Long Chunk, Long Flat	400 Grains IMR 4350	1401	1295	N/A	Bad Shot

Nomenclature:
1. N/A: Not applicable
2. Velocities in parenthesis are the mean estimates for equivalent powder weights and types. These are quite reliable and are plotted in Figure 5.

Fragment 1

No Recovery

Weight: 1.00 $\pm$ 0.01 grams
Length: 0.366 inches
Width: 0.340 inches

Fragment 2

No Recovery

Weight: 1.00 $\pm$ 0.01 grams
Length: 0.406 inches
Width: 0.300 inches

Fragment 3

Weight: 0.95 $\pm$ 0.01 grams
Length: 0.691 inches
Width: 0.308 inches

Fragment 4

No Recovery

Weight: 1.00 $\pm$ 0.01 grams
Length: 0.459 inches
Width: 0.413 inches

Fragment 5

Weight: 0.94 $\pm$ 0.01 grams
Length: 0.453 inches
Width: 0.316 inches

Fragment 6

Weight: 1.00 $\pm$ 0.01 grams
Length: 0.453 inches
Width: 0.321 inches

Fragment 7

Weight: 1.00 $\pm$ 0.01 grams
Length: 0.396 inches
Width: 0.340 inches

Fragment 8

No Recovery

Weight: 0.94 $\pm$ 0.01 grams
Length: 0.443 inches
Width: 0.316 inches

Fragment 9

No Recovery

Weight: 1.00 $\pm$ 0.01 grams
Length: 0.525 inches
Width: 0.387 inches

Fragment 10

Weight: 0.94 $\pm$ 0.01 grams
Length: 0.680 inches
Width: 0.382 inches

Fragment 11

No Recovery

Weight: 0.94 $\pm$ 0.01 grams
Length: 0.438 inches
Width: 0.378 inches

Fragment 12

No Recovery

Weight: 1.00 $\pm$ 0.01 grams
Length: 0.565 inches
Width: 0.300 inches

Figure 4. 15-Grain Bomb Fragment Shapes

Fragment 13

Weight: 1.00 ± 0.01 grams
Length: 0.482 inches
Width: 0.355 inches

Fragment 14

No Recovery

Weight: 1.00 ± 0.01 grams
Length: 0.643 inches
Width: 0.288 inches

Fragment 15

No Recovery

Weight: 0.94 ± 0.01 grams
Length: 0.395 inches
Width: 0.357 inches

Fragment 16

No Recovery

Weight: 0.94 ± 0.01 grams
Length: 0.490 inches
Width: 0.345 inches

Fragment 17

Weight: 0.94 ± 0.01 grams
Length: 0.770 inches
Width: 0.290 inches

Fragment 18

No Recovery

Weight: 1.00 ± 0.01 grams
Length: 0.455 inches
Width: 0.320 inches

Fragment 19

breakoffs

Weight: 0.94 ± 0.01 grams
Length: 0.505 inches
Width: 0.410 inches

Fragment 20

Weight: 1.00 ± 0.01 grams
Length: 0.539 inches
Width: 0.280 inches

Note: These ink blot copies of fragments are slightly larger than the actual specimens.

Figure 4. (Cont'd)

SECTION IV
SECONDARY OBJECTIVES

Table II data, obtained from Fig 5, reveals no significant relationship between depth of penetration as a function of presented area and perimeter of impacting fragments at 3000 ft/sec and 5000 ft/sec. At 1000 ft/sec there is a correlation with increasing penetration and decreasing impacting fragment presented area and perimeter.

Table III data shows that fragment penetration into Nu-Wood is a momentum rather than a kinetic energy effect. This results from the penetration to be a function of velocity rather than velocity squared. The striking velocity can be linearly approximated by:

$$V = CX$$

V = Striking velocity in ft/sec

C = 571 ft/sec· inches

X = Depth of penetration measured perpendicular to the Nu-Wood surface to center of gravity of fragment (inches).

Fragment breakoffs are located at the point where the fragment is found. Pieces will be found at the larger piece fragment location. No breakoffs were found along the Nu-Wood path.

An examination of bore sight, fragment entrance, and finalized position in Nu-Wood co-ordinates reveals no appreciable air deflection and Nu-Wood deflection of fragments. Air deflection could be attributed to the sabot aiming the fragment after exit from the Mann barrel. Since the Nu-Wood deflection is slight, no transformations are made on the perpendicular to Nu-Wood surface penetration data. All the penetration data in Figure 3 need not be corrected for the slight angular deflections in Nu-Wood.

Some other interesting facts found from testing are:

a. The recovered fragments had Nu-Wood clinging to them.

b. As the fragment goes deeper into the Nu-Wood it tends to make a large and less clean or sharp hole. This could be attributed to Nu-Wood building up on the fragment as it penetrates.

c. The Lexan sabot will be dented on its base from the fragment's initial momentum impulse.

d. For better air flight stability a sabot fitting a fragment is better than a sabot with a hole too large.

TABLE II. PRESENTED AREAS AND PERIMETERS OF IMPACTING 15-GRAIN BOMB FRAGMENTS

Shot No.	X(Depth of Penetration Perpendicular to Nu-Wood Surface to Estimated Center of Gravity of Fragment) (in.)	A(Presented Area of Impacting Fragment) (in.)	P(Perimeter of Impacting Fragment) (in.)	Striking Velocity (ft/sec)	$\frac{A}{P}$
43	5.50	0.062	1.000	4764	0.062
23	6.00	0.116	1.688	5012	0.069
24	7.00	0.070	1.062	4779	0.066
39	7.12	0.040	1.031	5117	0.039
30	8.75	0.029	0.859	4887	0.034
41	9.50	0.056	1.141	4559	0.049
46	9.75	0.058	0.953	4870	0.061
34	10.00	0.065	1.000	4626	0.065
21	10.50	0.064	1.031	4787	0.062
51	12.00	0.058	0.875	4963	0.066
25	12.62	0.062	0.969	4923	0.064
48	14.00	0.058	0.938	4961	0.062
8	5.50	0.074	1.078	2804	0.069
11	5.56	0.048	0.969	2876	0.050
58	6.00	0.086	1.094	3009	0.079
9	6.31	0.067	1.031	2849	0.065
52	7.38	0.067	1.125	2915	0.060
12	8.00	0.045	0.984	2875	0.046
5	1.69	0.068	1.516	933	0.045
7	1.75	0.067	1.109	837	0.060
54	2.00	0.055	1.031	908	0.053
3	2.19	0.055	1.016	908	0.054
2	2.25	0.021	0.766	907	0.027
4	3.12	0.026	0.625	1120	0.042

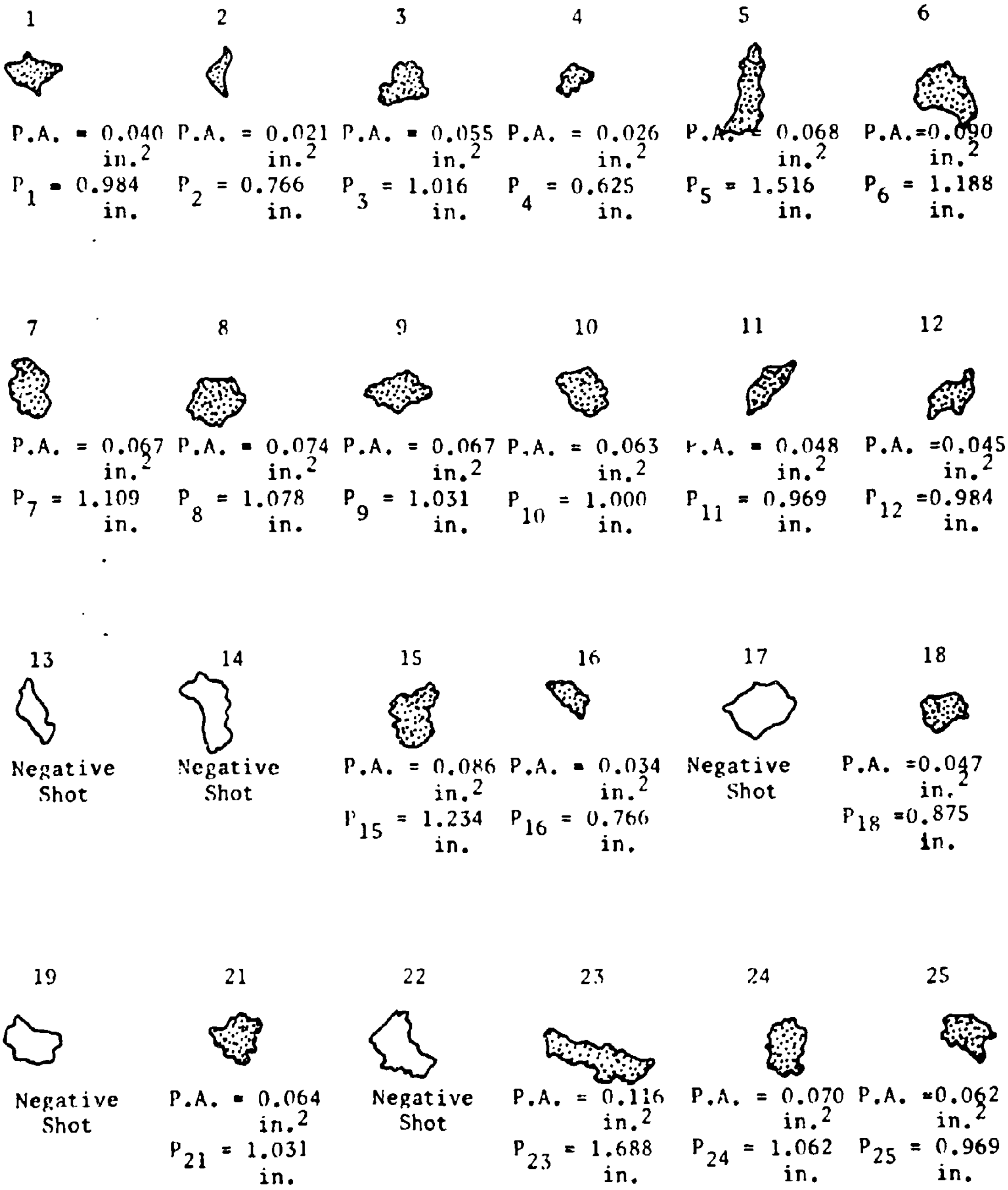
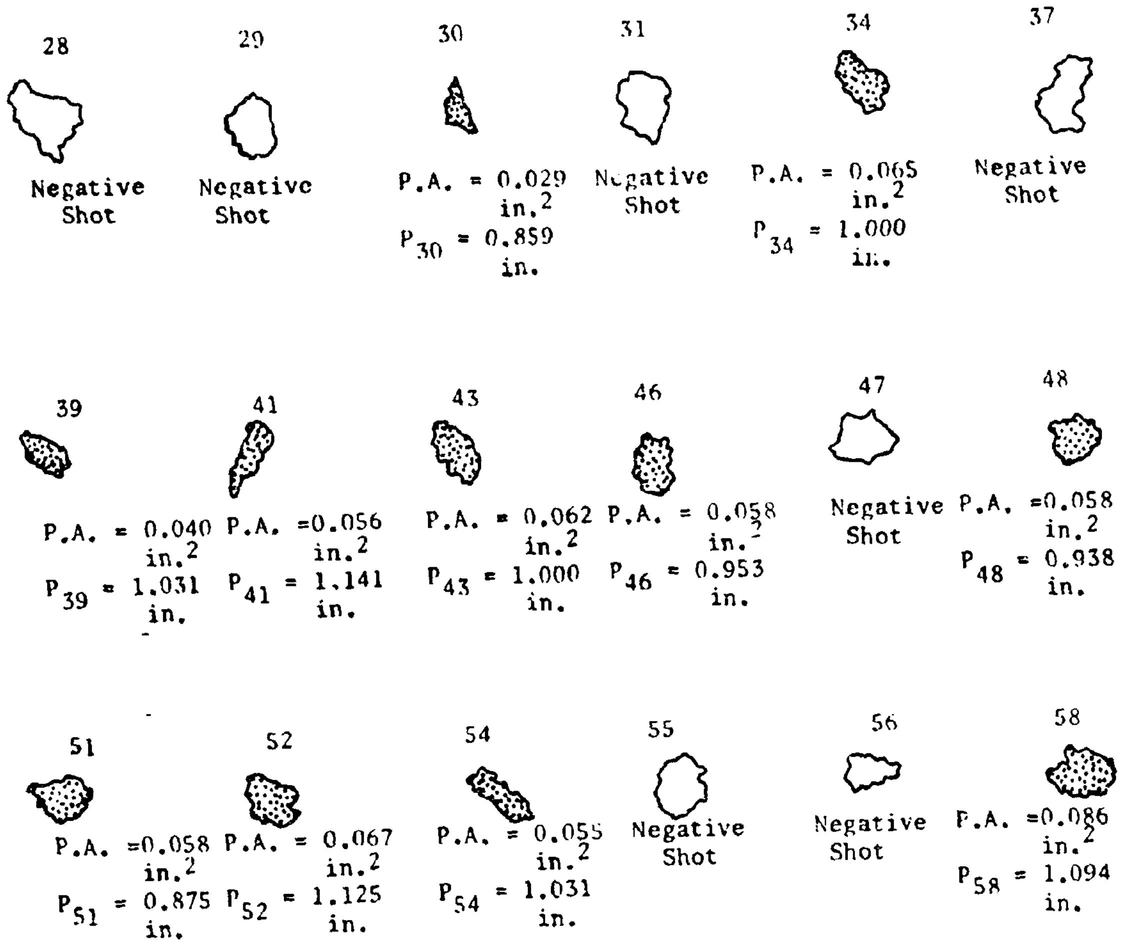


Figure 5. 15-Grain Bomb Fragment Impact Presented Areas and Perimeters



Note: 1. The Shot Number is listed above each fragment.
2. P.A. = Presented Area.
3. P_x = Perimeter for Shot X fragment.

Figure 5. (Cont'd)

TABLE III. MOMENTUM PENETRATION INTO NU-WOOD

Shot No.	V(Approximate Striking Velocity) (ft/sec) (K = thousand)	V^2	A(Presented Area of Impacting Fragment) (in.^{2})	P(Perimeter of Impacting Fragment (in.)	X(Penetration Measured Perpendicular to Nu-Wood Surface to Center of Gravity of Fragment) (in.)	Normalized Penetration $\frac{X}{1.75}$
7	1 K	1 K^2	0.067	1.109	1.75	1.00
9	3 K	9 K^2	0.067	1.031	[illegible]	3.61
21	5 K	25 K^2	0.064	1.031	[illegible]	6.00
3	1 K	1 K^2	0.055	1.016	2.19	1.25
11	3 K	9 K^2	0.048	0.969	5.56	3.18
7	1 K	1 K^2	0.067	1.109	1.75	1.00
8	3 K	9 K^2	0.074	1.078	5.50	3.14
7	1 K	1 K^2	0.067	1.109	1.75	1.00
24	5 K	25 K^2	0.070	1.062	7.00	4.00
9	3 K	9 K^2	0.067	1.031	6.31	3.61
24	5 K	25 K^2	0.070	1.062	7.00	4.00
9	3 K	9 K^2	0.067	1.031	6.31	3.61
25	5 K	25 K^2	0.062	0.969	12.62	7.21
5	1 K	1 K^2	0.068	1.516	1.69	0.97
41	5 K	25 K^2	0.056	1.141	9.50	5.43

Linear Approximation:

$$V = C\,(X) \qquad C = \frac{1K}{1.75''} = 571 \text{ ft/sec}\cdot\text{in.}$$

SECTION V
CONCLUSIONS

The fundamental conclusions are:

a. The existing Thor equation predictions for cylinders do not fit actual 15-grain bomb fragment data.

b. Depth of penetration into Nu-Wood is not a reliable method to predict the velocity of 15-grain bomb fragments.

c. The fragments are momentum and not kinetic energy penetrators.

d. The depth of penetration is not a primary function of the presented area and perimeter of the impacting fragments for 3000 ft/sec and 5000 ft/sec striking velocities. Shots at 1000 ft/sec indicate that depth of penetration is a primary function of the perimeter and presented area of the fragments.

REFERENCES

1. Section II of USAF TH 61A1-3-7 titled, "JMEM/AS Joint Service Test Procedures for High Explosive Bomb and Bomblets."

2. Malick, Donald, The Calibration of Wallboard for the Determination of Particle Speed, Ballistic Analysis Laboratory, TR-61, May 1966, page 16.

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13 ABSTRACT The primary objective of this program was to define a function between the striking velocity for 15-grain random shaped bomb fragments and their depth into the wallboard trade named Nu-Wood. These fragments were fired from a 20mm Mann Barrel into bundled Nu-Wood. The fragments were lightly filed to fit into a $0.97 \le w \le 1.03$ gram weight range. The striking velocities were in the 500 ft/sec to 5000 ft/sec range. The graph of fragment striking velocity as a function of depth into Nu-Wood showed a wide range of depths for approximately 1000 ft/sec, 3000 ft/sec, and 5000 ft/sec striking velocites. A least squares curve would not be valuable since the penetration spread is too wide at given velocities. Fragment penetration into Nu-Wood from firing cylinders does not give a realistic picture of 15-grain actual bomb fragmentation spread. The fragment penetration into Nu-Wood was found to be a momentum as opposed to a kinetic energy effect. The depth of penetration is not a primary function of the presented area and perimeter of the impacting fragments for 3000 ft/sec and 5000 ft/sec velocities. Shots at 1000 ft/sec reveal a dependence on the presented area and perimeter of the impacting fragment.

14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
Bombs						
Bomb Fragments						
Wallboard						
Nu-Wood						
Velocity Determinations						
Penetration						

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